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Toxicity of Textile Mill Effluents to Freshwater and Estuarine Algae Crustaceans and Fishes

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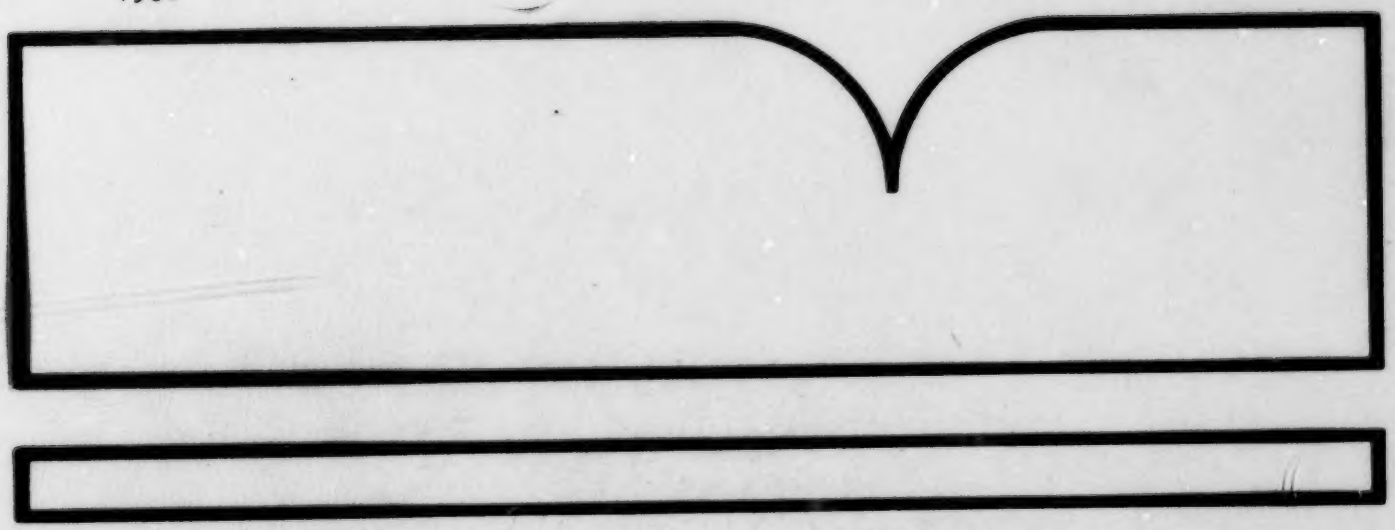

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JOURNAL ARTICLE

TOXICITY OF TEXTILE MILL EFFLUENTS TO FRESHWATER AND ESTUARINE ALGAE, CRUSTACEANS AND FISHES†

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ABSTRACT

The toxicity of secondary waste effluents from textile manufacturing plants was determined with freshwater (Selenastrum capricornutum, Daphnia pulex, Pimephales promelus) *and estuarine* (Skeletonema costatum, Palaemonetes pugio, Cyprinodon variegatus) *organisms.* Daphnia pulex *was generally the most sensitive animal, but no animal responded to all wastes. Growth of the algae* S. capricornutum *and* S. costatum *was affected by all wastes, through either inhibition or stimulation. Some wastes were stimulatory to* S. costatum *at low concentrations (<1%) but inhibitory at high concentrations (>50%). The concentration of waste that stimulated growth of* S. costatum *by 20% compared with controls (SC_{20}) was calculated and used with EC_{50} values for the survival of* D. pulex *to estimate the potential impact of the wastes in relation to volume of discharge.*

INTRODUCTION

Increased industrial production and population growth pose a threat to natural waters in the United States because industrial and municipal wastes contain a variety of substances known to be toxic to aquatic organisms.

The US Department of Commerce (1972) predicted that textile manufacturing will increase approximately 3·5 times between 1975 and 2020. A growth rate of approximately 4·5 times was predicted for textile industries in coastal cities. The US Environmental Protection Agency's (EPA) Industrial Environmental Research

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Laboratory at Research Triangle Park (IERL–RTP), North Carolina, has conducted an extensive evaluation of the chemical constituents and biological effects of 23 wool and fabric finishing plants in the textile industry in the United States. The purpose of the EPA study was to provide data on the composition and toxicity of textile plant effluents so that the best available technology could be applied to their disposal.

Table 1 gives some chemical characteristics of the wastes (USEPA, 1978). There were wide variations in chemical composition and the wastes did not resemble each

TABLE 1

CHARACTERISTICS OF FILTERED SECONDARY EFFLUENT USED IN TOXICITY TESTS (USEPA, 1978). ND = NOT DONE

Waste	*Colour units*[a]	*mg/litre*					*Number of organic compounds*	*Number of elements*
		Nitrate	*Nitrite*	*Ammonia*	*Ortho-phosphate*	*Total Kjeldahl nitrogen*		
A	2000	1·90	0·06	12·80	1·00	21·30	6	56
B	90	0	0	2·50	7·30	4·20	4	55
C	1920	23·30	4·60	3·40	1·08	1·85	7	62
D	1625	0·08	7·50	0·20	1·60	4·50	3	ND
E	30	79·20	0·02	3·40	1·11	6·75	7	46
F	80	0	0·04	1·50	0·56	14·80	8	56
G	500	1·30	0·08	0·04	5·02	12·00	6	37
H	500	0·69	16·80	0·02	0·06	5·50	3	ND
J	1375	0·29	11·90	1·25	0·28	2·30	5	ND
K	270	4·40	0·06	0·40	0·82	5·25	7	49
L	370	13·50	0·86	0·50	0·88	1·90	2	46
M	500	0·30	0·27	0·84	0·55	6·15	3	ND
N	90	5·50	0	12·80	11·20	17·00	7	60
P	250	0·08	7·30	0·20	0·20	2·90	5	ND
R	2000	0·02	1·82	2·60	0·06	19·80	3	ND
S	240	4·40	0·03	1·65	3·10	40·00	8	51
T	350	0·80	0·04	13·60	6·40	30·20	3	45
U	2480	0·80	0	5·44	2·96	11·30	6	41
V	500	0·88	0·26	1·26	0·11	6·30	2	42
W	1900	12·30	0·15	0·38	0·08	7·40	2	58
X	10	0·03	0·44	0·65	0	5·25	6	38
Y	250	0·05	8·50	1·90	9·90	5·75	8	ND
Z	750	0·94	0	0·85	0·40	4·75	5	ND

[a] APHA, AWWA, WPCF (1975).

other closely. In addition, each waste was analysed for 77 elements and 44 organic chemicals (USEPA, 1978) and all contained a variety of heavy metals and organic molecules. Organic and elemental composition of waste sample X is given in Table 2 as an example of their chemical complexity. The data are expressed as concentrations of organic compounds in whole waste and elements in particulate and liquid phases.

The purpose of the work reported here was to evaluate the potential hazard of liquid secondary wastes from the 23 textile plants to aquatic organisms. Acute

TABLE 2
ORGANIC AND INORGANIC COMPOSITION OF WASTE X (USEPA, 1978)

Organic (μg/litre)
Diethyl phthalate (3·2)
Bis (2-ethylhexyl) phthalate (2·3)
Hexachlorobenzene (0·5)
Toluene (39·6)
Trichlorofluoromethane (35·0)
1,1,2,2-tetrachloroethylene (40·5)

Inorganic particulate (g/m³)
Bismuth (<0·09)
Lead (5·0)
Thallium (<0·06)
Tungsten (0·06)
Tantalum (0·08)
Hafnium (<0·1)
Ytterbium (<0·09)
Erbium (<0·06)
Gadolinium (<0·06)
Samarium (<0·06)
Neodymium (0·06)
Praseodymium (0·06)
Cerium (0·2)
Lanthanum (0·09)
Barium (22)
Iodine (0·09)
Antimony (2·4)
Tin (0·44)
Cadmium (0·06)
Molybdenum (0·1)
Niobium (0·06)
Zirconium (0·4)
Yttrium (0·08)
Strontium (1·3)
Rubidium (0·4)
Bromine (17)

Inorganic, particulate
Arsenic (<0·06)
Gallium (0·06)
Zinc (410)
Copper (27)
Nickel (7)
Cobalt (2·7)
Iron (1300)
Manganese (2·5)
Chromium (12)
Vanadium (0·4)
Titanium (4·7)
Scandium (0·06)
Calcium (1200)
Potassium (53)
Chlorine (17)
Sulphur (110)
Phosphorus (2400)
Silicon (880)
Aluminium (640)
Sodium (2200)
Fluorine (38)
Lithium (0·15)

Inorganic, filtrate (g/m³)
Lead (0·03)
Tungsten (<0·002)
Hafnium (<0·002)
Ytterbium (<0·002)
Lanthanum (0·001)
Barium (0·13)
Iodine (0·04)
Antimony (1·9)
Tin (0·004)

Inorganic, filtrate
Molybdenum (0·005)
Yttrium (0·007)
Strontium (0·14)
Rubidium (0·023)
Bromine (2·5)
Arsenic (0·022)
Germanium (0·005)
Gallium (0·001)
Zinc (0·14)
Copper (0·87)
Nickel (0·006)
Cobalt (0·12)
Iron (2·5)
Manganese (0·028)
Chromium (0·027)
Vanadium (0·026)
Titanium (0·018)
Scandium (<0·002)
Calcium (23)
Potassium (9)
Chlorine (130)
Sulphur (29)
Phosphorus (29)
Silicon (1·8)
Aluminium (8·2)
Magnesium (4·6)
Sodium (33)
Fluorine (11)
Lithium (0·052)

toxicity was evaluated by bioassays with freshwater and estuarine organisms. Data from bioassays were related to detailed chemical analyses and to effluent discharge volumes in order to estimate the potential effect of each waste stream.

MATERIALS AND METHODS

Secondary effluents from 23 textile mills in the eastern United States were collected by personnel of the Monsanto Research Corporation, Dayton, Ohio, under contract to EPA. Eight samples of equal volume were collected at approximately hourly intervals throughout the normal working day at each mill. The subsamples were composited, apportioned into glass bottles, packed in ice in insulated containers and shipped by air to several laboratories: (1) Newtown Fish Toxicology Station, Cincinnati, Ohio; (2) Environmental Research Laboratory, Gulf Breeze,

Florida; (3) Environmental Research Laboratory, Corvallis, Oregon and (4) Bionomics Marine Laboratory, Pensacola, Florida. The first three are EPA laboratories, the fourth is a private research laboratory. Bioassays were initiated immediately upon receipt of the samples. Unused portions were stored in a refrigerator at 4°C.

Details of biological methods used here are described in the US Environmental Protection Agency, IERL–RTP Procedures Manual: Level 1 (1977). All 23 samples were tested with freshwater organisms, whereas 14 were tested with estuarine species.

Freshwater bioassays

Alga: The Algal Assay Bottle Test (USEPA, 1971), using *Selenastrum capricornutum* Printz, was used to measure the effects of the wastes on growth. Each waste sample was treated in two ways before testing: (1) filtered and then autoclaved and (2) filtered only. Tests were not carried out on untreated waste. The treated wastes were diluted to 2, 5, 10 and 20% with filtered well water and growth response was measured as net biomass in relation to the growth of control cultures in filtered, autoclaved well water after 14 days.

Animals: Ten fathead minnows *Pimephales promelus* Rafinesque were exposed to each dilution of waste in 20-litre volume glass jars that contained 15 litres of test solution. Static test conditions were: temperature, 21°C; time of exposure, 96 h; average standard length of fishes, 33 mm (range 28 to 44 mm); average weight 0·29 g (range 0·18 to 0·80 g). Fish were exposed to standard laboratory water (control) and to 4·7, 7·8, 13·0, 21·6, 36, 60 and 100% waste. Waste solutions were not aerated, but oxygen concentrations were measured at 24-h intervals. At the end of each 24-h period, the number of surviving fish was recorded and the dead fish removed.

The LC_{50}, i.e. the estimated dilution that would kill 50% of the fish, was determined statistically by probit analysis or by moving average angle.

Ten *Daphnia pulex* Straus were exposed to the same dilutions of waste as *P. promelus* in 200 ml of solution in 250-ml volume beakers. Test duration was 48 h and EC_{50} (the estimated dilution that affected 50% of exposed animals) was used to express effect. The criterion for effect was lack of movement and the EC_{50} was statistically determined by probit analysis or by moving average angle.

Saltwater bioassays

Alga: The test alga was *Skeletonema costatum* (Greville) Clevel., a chain-forming diatom of wide geographical range. Stocks were maintained in artificial seawater medium (Rila Salts®) (Rila Products, Teaneck, New Jersey; reference to trade names does not constitute recommendation for use or endorsement by the US Environmental Protection Agency) of 30 parts per thousand (‰) salinity prepared from deionised water and fortified with metals, vitamins and minor salts. They were illuminated by 'cool white' fluorescent tubes at approximately 4000 lux in a cycle of 14 h of light followed by 10 h of darkness. Temperature was 20° ± 1°C.

Control growth medium was prepared with deionised water and test medium with undiluted liquid waste. Rila Salts were added to bring the salinity to 30‰ and trace metals, vitamins and minor salts were added at concentrations that support approximately half the population density of full strength nutrient medium. Waste was diluted with control medium. This nutrient-deficient medium, without a chelator, allowed detection of inhibition and stimulation of growth at the test pH of 8·1. In range-finding tests, dilutions were 0·1, 1·0, 10, 25, 50, 75, 95 and 100%. In definitive tests, dilutions were chosen so as to allow greater than 50% growth in some tubes and less than 50% growth in others for calculation of the EC_{50}.

Growth tests were performed in triplicate in sterile, optically matched test tubes (25 × 200 mm, Bellco Glass Co., Vineland, New Jersey). Twenty-five millilitres of each waste dilution were added to each of three tubes; control tubes contained the same volume of growth medium prepared with deionised water. One millilitre of algal suspension containing approximately 1000 cells in the logarithmic phase of growth per millilitre was added to each tube. Similar tubes not inoculated with algae served as optical blanks. All tubes were incubated on a rotary shaker at 60 excursions per minute, 20° ± 0·5 °C, and 4000 lux. The lighting cycle was 14 h light followed by 10 h darkness.

After incubation for 96 h, the absorbance of each culture was measured spectrophotometrically at 525 mm on a Fisher Electrophotometer® II (Fisher Scientific Co., Pittsburgh, Pennsylvania). Absorbance values of uninoculated blank tubes were subtracted from those of inoculated tubes to determine absorbance due to algae.

Response of *Sk. costatum* was estimated (1) as the calculated concentration that would inhibit growth by 50% (EC_{50}) and (2) by a concept introduced here: the calculated concentration that would stimulate growth by 20% (SC_{20}). Stimulation or inhibition of algal growth was calculated by plotting the non-linear regression of absorbance on waste concentration by an equation developed for these studies:

$$Y = \frac{A}{1 + B\uparrow(X - C)} - \frac{A}{1 + D\uparrow(X - E)}$$

where A = mean maximum biomass, B = increasing slope, C = effluent concentration (increasing slope) where $Y = 0{\cdot}5 \times A$, D = decreasing slope, E = effluent concentration (decreasing slope) where $Y = 0{\cdot}5 \times A$, X = range of effluent concentrations tested and Y = estimated population density over range of X. For derivation and application of this model, see Bahner & Oglesby (in press). Calculations were made on a Digital Equipment Corporation PDP 11/45 computer. The EC_{50} and SC_{20} were calculated from the regression curve.

On average, algal growth stimulation of approximately 20% above the control value (SC_{20}) can be considered to be a statistically significant increase in growth in these tests. The mean upper 95% confidence interval for algal growth in control cultures was 17% above the control mean growth value in 20 textile and other

industrial effluent assays. Therefore, growth stimulation greater than 17% above control was a significant response. To predict a number that represents a statistically significant increase in growth requires that the standard deviation of the predicted value also be considered. For 20 effluent assay analyses of textile and other wastes, 27% predicted growth stimulation that was significant ($\alpha = 0{\cdot}05$) as compared with control growth (test of differences between two means; Zar, 1974). This value supports the concept of SC_{20}, which can be used as an index of significant algal growth stimulation in effluent bioassays.

Animals: Juvenile sheepshead minnows *Cyprinodon variegatus* Lacépède, and grass shrimp *Palaemonetes pugio* Holthius were collected from estuarine marshes near Pensacola, Florida. They were held for at least two days in flowing water of approximately 10‰ before exposure to waste.

Five animals were exposed to each dilution in three litres of solution in four-litre volume glass jars. All static exposures were carried out in duplicate under the following conditions: temperature, 20° ± 1°C; salinity, 10‰; pH, 8·1; time of exposure, 96 h.

Salinity of the effluents was increased to 10‰ by the addition of Rila Salts. Control and dilution water were prepared from Rila Salts and glass-distilled water; pH was adjusted to 8·1 with dilute NaOH.

Each effluent sample was subjected to a 48-h range finding test. If no deaths occurred in undiluted waste, the exposure was extended to 96 h. If mortality was equal to, or less than, 50% after 96 h, no further tests were carried out. If mortality was greater than 50%, 96-h definitive tests were undertaken.

Dilutions of wastes that would kill 50% of the animals in 96 h (LC_{50}) were calculated by straight-line graphical interpolation.

RESULTS

In all animal exposures, percentage saturation of media by oxygen was never lower than 40%; therefore, effects were not due to oxygen deficiency.

Algae

All 23 waste samples affected growth of the freshwater alga *S. capricornutum* (Table 3). Filtered samples either stimulated or inhibited growth: 8 (35%) were inhibitory and 15 (65%) were stimulatory. However, since the maximum concentration tested was 20%, effects at higher concentrations could not have been detected.

Filtration and autoclaving may have changed the bioactive properties of some of the waste samples. Autoclaving reduced the stimulatory effects of samples B and P and the inhibitory effects of samples, A, L and Z; sample L changed from highly inhibitory to highly stimulatory and sample P became slightly toxic.

TABLE 3

EFFECTS OF TEXTILE MILL SECONDARY EFFLUENT ON GROWTH OF FRESHWATER (*S. capricornutum*) AND ESTUARINE (*Sk. costatum*) ALGAE. *S. capricornutum* WAS GROWN IN 20% WASTE. EXCEPTIONS ARE NOTED BY * WHICH DENOTES 2% WASTE. NE = NO EFFECT; ND = NOT DONE

Waste	S. capricornutum				Sk. costatum	
	Filtered		*Filtered and autoclaved*		*Untreated*	
	Percentage inhibition	*Percentage stimulation*	*Percentage inhibition*	*Percentage stimulation*	EC_{50}	SC_{20}
A	53	0	33	0	ND	ND
B	0	83	0	44	NE	0·5
C	0	187	0	146	76	1·5
D	0	100	0	125	ND	ND
E	95*	0	95*	0	ND	ND
F	0	598	0	866	84	NE
G	0	390	0	578	59	2·8
H	92	0	95	0	ND	ND
J	0	76	0	217	ND	ND
K	0	57	0	243	75	1·0
L	81	0	0	98	1·5	NE
M	0	149	0	291	ND	ND
N	95*	0	95*	0	2·0	NE
P	0	38	5	0	9·0	NE
R	95	0	93	0	ND	ND
S	0	382	0	365	NE	2·3
T	0	1911	0	2362	66	2·0
U	0	377	0	639	NE	1·5
V	0	232	0	503	93	21·8
W	95	0	95	0	50	1·5
X	0	163	0	348	NE	0·5
Y	0	261	0	365	ND	ND
Z	84	0	17	0	ND	ND

All of the 14 waste samples tested with the marine alga *Sk. costatum* affected growth. Samples F, L, N and P were inhibitory only, samples B, S, U and X were stimulatory only and samples C, G, K, T, V and W were stimulatory at low concentrations and inhibitory at high concentrations (Table 3). Figure 1 illustrates the three types of response. Overall, 71% of the samples were inhibitory and 71% were stimulatory to the marine alga.

Animals

Generally the fishes were less sensitive to the wastes than the crustaceans, based upon LC_{50} and EC_{50} values (Table 4). In freshwater, *D. pulex* was usually more sensitive than *P. promelus*. In saltwater, *P. pugio* was always more sensitive than *C. variegatus*. *Daphnia pulex* was more sensitive than *P. pugio* in 8 out of 12 tests, but it is not known if salt added to the medium affected the toxicity of waste chemicals in the marine tests.

Overall, 61% of the wastes were toxic to *D. pulex*, whereas 40% were toxic to *P. promelus* and 53% to *P. pugio* and *C. variegatus*.

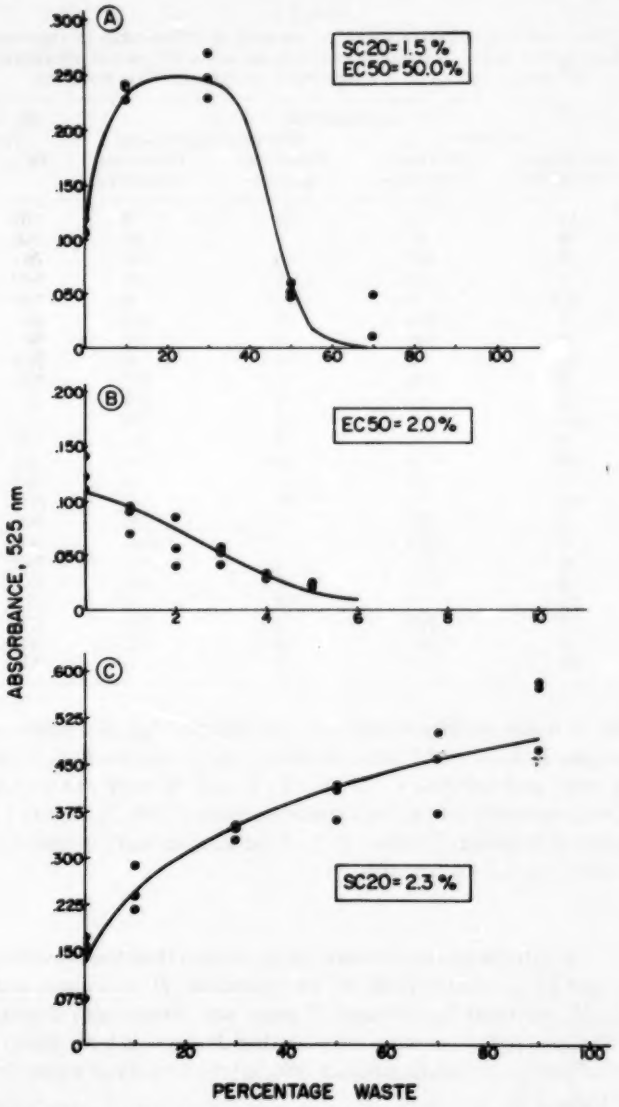

Fig. 1. Effects of three textile wastes on growth of *Skeletonema costatum* after 96 h exposure. Ⓐ Stimulation at low concentrations, inhibition at high concentrations; Ⓑ Inhibition only; Ⓒ Stimulation only. EC_{50} = the calculated concentration that would inhibit growth by 50%; SC_{20} = the calculated concentration that would stimulate growth by 20%.

TABLE 4

TOXICITY OF TEXTILE MILL SECONDARY WASTES TO CRUSTACEANS AND FISHES. NUMBERS ARE EC_{50} (*D. pulex*) AND LC_{50} (*P. promelus*, *P. pugio*, *C. variegatus*) VALUES IN PERCENTAGE EFFLUENT. NAT = NOT ACUTELY TOXIC; ND = NOT DONE

Waste	*Freshwater*		*Estuarine*		*Most sensitive species*
	D. pulex	P. promelus	P. pugio	C. variegatus	
A	9·0	19·5	21·2	62·0	*D. pulex*
B	NAT	NAT	NAT	NAT	—
C	41·0	46·5	12·8	69·5	*P. pugio*
D	NAT	NAT	ND	ND	—
E	7·8	NAT	40/100[a]	NAT	*D. pulex*
F	81·7	NAT	NAT	NAT	*D. pulex*
G	62·4	64·7	20/100[c]	40/100[a]	*D. pulex*
H	40/100[a]	NAT	ND	ND	*D. pulex*
J	NAT	NAT	ND	ND	—
K	NAT	NAT	NAT	NAT	—
L	28·0	23·5	NAT	100	*P. promelus*
M	60·0	NAT	ND	ND	*D. pulex*
N	100/100[b]	48·8	26·3	47·5	*D. pulex*
P	NAT	NAT	ND	ND	—
R	6·9	16·5	ND	ND	*D. pulex*
S	NAT	NAT	20/100[c]	20/100[c]	*P. pugio*
					C. variegatus
T	NAT	46·5	34·5	68·0	*P. pugio*
U	12·1	NAT	NAT	NAT	*D. pulex*
V	9·4	36·0	NAT	NAT	*D. pulex*
W	6·3	55·2	19·6	37·5	*D. pulex*
X	NAT	NAT	NAT	NAT	—
Y	NAT	NAT	ND	ND	—
Z	42·6	NAT	ND	ND	*D. pulex*

[a] 40% of the animals dead in 100% waste, 96 h.
[b] All fish dead in all concentrations, 24 h.
[c] 20% of the animals dead in 100% waste, 96 h.

DISCUSSION

The waste samples tested were mixtures of organic and inorganic substances and it would be impossible to predict their biological effects from chemical analyses alone because: (1) acute toxicity of most substances, or of mixtures, to aquatic organisms is not known and (2) the organisms varied widely in response to each waste. For example, waste X (Table 2) contained six organic compounds and 50 elements not present in the organics, but was not toxic to animals or algae. It was, however, stimulatory to algae. Also, based on chemical analyses reported by USEPA (1978), we detected no obvious relationship between biological effects and colour, biological oxygen demand or chemical oxygen demand, or concentration of sulphide, phenol, suspended solids, cyanide, organic carbon, total organics extracted with methylene chloride, metals, ammonia, nitrate, nitrite, Kjeldahl nitrogen, ortho-phosphate or total phosphorus. It is likely that, in a complex waste, bioactivity is related to interactions amongst the components themselves, with no single

substance having a dominant effect. For example, growth stimulation was not correlated to high concentrations of nitrate or phosphate and growth inhibition was not correlated to concentrations of organic substances or metals.

Algae were useful indicators of potential pollution because they responded by stimulation, inhibition or both, to all wastes, whereas the animals did not respond to all wastes. When algal growth stimulation occurred, it was at a relatively low concentration, suggesting that symptoms of eutrophication may be expected in the vicinity of the outfall.

The combined algal and animal data suggest that both growth stimulants and toxicants were present in some wastes. For example, samples C, U and W were toxic to animals, with EC_{50} values between 6·3 and 12·8%. Their SC_{20} values with *Sk. costatum* were 0·5% (waste C) and 1·5% (wastes U and W). Eleven wastes (B, D, G, J, K, M, S, T, V, X and W) had little or no toxic effect on animals but were highly stimulatory to algae; four (A, E, N and R) were toxic to both algae and animals but only two (H and Z) were toxic to algae with little or no effect on animals.

The data given here were collected for estimation of possible effects of complex wastes on aquatic systems. To do so, it was assumed that the LC_{50}, EC_{50} or SC_{20} could be used to determine possible effects of an effluent in relation to its discharge volume. The expression:

$$\text{MEU/d} = \left(\frac{100}{LC_{50},\ EC_{50},\ \text{or}\ SC_{20}} \right) (\text{discharge rate})$$

where MEU/d = million effective units per day, was used to estimate relative potential impact of the 14 wastes tested with all organisms. *Skeletonema costatum* was the most sensitive organism, its SC_{20} or EC_{50} being the lowest value in 12 cases. *Daphnia pulex* was the most sensitive organism in two of the wastes.

TABLE 5

RELATIVE POTENTIAL IMPACT, IN MEU/day, OF 14 SECONDARY TEXTILE MILL WASTES TESTED WITH FRESHWATER AND ESTUARINE ALGAE, CRUSTACEANS AND FISHES. MEU = MILLION EFFECTIVE UNITS

Waste	*Discharge* ($m^3/day \times 10^3$)	*Most sensitive organism*	*Response*	*Lowest value*	*MEU/day* $\times 10^{-3}$
B	4·5	*Sk. costatum*	SC_{20}	0·5	900
C	3·8	*Sk. costatum*	SC_{20}	1·5	253
F	7·6	*D. pulex*	EC_{50}	81·7	9
G	7·6	*Sk. costatum*	SC_{20}	2·8	271
K	9·5	*Sk. costatum*	SC_{20}	1·0	950
L	2·8	*Sk. costatum*	EC_{50}	1·5	187
N	3·8	*Sk. costatum*	EC_{50}	2·0	190
P	4·5	*Sk. costatum*	EC_{50}	9·0	50
S	4·7	*Sk. costatum*	SC_{20}	2·3	204
T	2·3	*Sk. costatum*	SC_{20}	2·0	115
U	1·1	*Sk. costatum*	SC_{20}	1·5	73
V	3·0	*D. pulex*	EC_{50}	9·4	32
W	1·0	*Sk. costatum*	SC_{20}	1·5	67
X	9·8	*Sk. costatum*	SC_{20}	0·5	1960

This approach allows for the ranking of complex wastes with regard to their potential effects upon receiving waters (Table 5). Sample X, which had a low SC_{20} and a high discharge rate, is judged to have the greatest potential for adverse effect upon its receiving water. Waste W, with a low SC_{20} and a low discharge rate, was judged as having a relatively low potential for adverse effect.

Algal data are not widely used for setting water quality standards because algae are not usually as sensitive to individual organic pollutants as are invertebrates or fishes (USEPA, 1976). Our data show that *Sk. costatum* was the most sensitive organism to most of the complex wastes tested. It was especially valuable because such wastes often contain nutrients and toxicants that animal tests cannot detect. We suggest that algal tests should be an integral part of testing programmes for complex wastes. Responses of algae and animals can be used to test effluents before and after application of treatment technology for the removal of toxic and stimulatory substances.

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